Draft

Fairfax County Stream Physical Assessment Protocols

Prepared for

Stormwater Management Branch

Fairfax County, VA

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Introduction

Fairfax County has been developing an overall watershed management program that will help it to plan and prioritize watershed management. The program began with data collection through development of a comprehensive GIS system, a countywide bioassessment program, and field determination of stream perenniality, culminating in the issuance of the County's Stream Protection Strategy Baseline Study (Fairfax County Stormwater Planning Division, DPWES, January 2001).

The data collection effort will continue with the initiation of this countywide physical and habitat assessment of streams. As the data are compiled, the County will have a thorough understanding of each stream and watershed and will be able to integrate the data to anticipate, prevent, mitigate, and correct stormwater impacts in coordination with the County's land use goals. The addition of habitat information to the Stream Evaluation program will allow a more comprehensive assessment of the stream conditions. Stream aquatic integrity in urban settings is directly affected by physical changes in the watershed, some of which result in the degradation of the chemical and/or physical condition of the stream. Habitat information is extremely important for discriminating between physical and chemical effects. The habitat information can be integrated with the historic and ongoing biological and chemical data collected by Fairfax County to develop comprehensive tools that predict the effects of watershed changes on stream features and integrity.

This document includes the protocols for the following:

- Characterizing stream and riparian zone habitat conditions
- Identifying erosion and pollution problems associated with infrastructure and other factors
- Making visual observations about general water quality conditions
- Classifying stream shape using techniques based on hydrogeomorphic conditions
- Collecting the data in uniform and standard process so they are accurate and reproducible

Purpose of this Document

The purpose of this document is to provide a practical, technical reference for conducting stream assessments. This document is designed to be dynamic and periodically reviewed and updated through the course of the project. The document is designed to describe operating procedures for collecting and recording stream assessment data. Essential to this project, this document establishes procedures for maintaining uniform operational and quality control guidance. Compliance with these procedures is essential to produce accurate and reliable data. This document is intended for use as a training resource as well as a technical manual for experienced personnel. Deviation from the operating procedures presented, must be documented and cleared by Fairfax County.

Purpose for a Stream Physical Assessment

The protocols presented in this document will be used for the stream physical assessment. It will provide information on the habitat conditions (habitat assessment), impacts on the stream from specific infrastructure and problem areas (infrastructure inventory), general stream characteristics, and a geomorphic classification of stream type. A baseline assessment will be conducted on 900 miles of stream throughout the county. The assessment results will be fed into the watershed management planning evaluations to determine appropriate management scenarios. Although this project does not specifically address watershed management planning , the results of the project will tie directly into the watershed planning process that the County is launching concurrently through the SPS program. The SPS program elements include:

- **Bioassessment** —Macroinvertebrate and fisheries sampling at selected stations throughout the county (1997 to Present)
- **Stream Perenniality Evaluation** —Field identification of the perennial/intermittent stream boundary (2001 to Present)
- **Stream Physical Assessment** —Countywide evaluation of habitat and stream characteristics for entire perennial stream channel network. (2002 to 2003)
- **Watershed Management Planning** —Development of watershed management plans for each major watershed within the county. (2002 to 2007)

Protocol Development

Habitat Assessment

The habitat assessment protocols and metrics presented here were used on several watershed management projects for documenting the stream physical conditions. The protocols were developed from existing sources, tested and documented in the scientific literature, and recommended by the U.S. Environmental Protection Agency (USEPA). The following discussion summarizes how "visual based" stream habitat assessment protocols were selected and adapted for the watershed wide management programs.

Several techniques have been developed for assessing the habitat quality of streams. Historically, many of these focused on developing habitats for maintaining certain fish species for commercial and recreation activities, rather than measuring overall system aquatic integrity for the purpose of meeting Clean Water Act goals. Table 1 describes habitat assessment protocols developed by Rankin (1995).

TABLE 1
Selected Listing of Habitat Indices Used in North America Over Past 30 Years

Index/Methodology	Purpose	Reference
Habitat Evaluation Procedures/Habitat Suitability Index (HEP/HSI)	Relate habitat quality to single species carrying capacity	Terrell (1984)
Habitat Quality Index (HQI)	Assess habitat as predictor of trout standing crop	Layher and Maughan (1985), Binns and Eiserman (1979)
Biological Stream Classification (BSC)	Use habitat quality with IBI to determine biotic potential of a stream reach	Illinois EPA (1989), Hite (1988)
Transect Method	Assess various aspects of stream habitat by taking measurements along transects in a reach	Dunham and Colotzi (1975), Platts et al. (1983), Armour et al. (1983), Duff et al. (1989)
Habitat Diversity/complexity	Calculate Shannon index using substrate, depth, and velocity	Gorman and Karr (1978), Schlosser (1982)

TABLE 1
Selected Listing of Habitat Indices Used in North America Over Past 30 Years

Index/Methodology	Purpose	Reference
Habitat Index (HI)	Compare present status to pristine conditions (Missouri's habitat quality index)	Fajen and Wehness (1982)
Habitat Condition Indicator (HCI)	Indicate habitat condition for stream bank and instream components	Duff et al. (1989)
Biological Condition Index (BCI/DAT)	Assess species diversity using habitat, species dominance, and taxa	Winget and Mangum (1979), Mangum (1986)
IFIM	Determine flow needs of stream fish species	Bovee (1982, 1986)
Rosgen	Classify stream channel and riparian characteristics based on fluvial geomorphology and stream conditions.	Rosgen (1985)
Ohio EPA QHEI	Perform visual habitat assessment correlated with fish community conditions (e.g., IBI)	Rankin (1989, 1991) Ohio EPA (1989)
RBP	Perform habitat evaluation based on stream classification guidelines for Wisconsin	Barbour and Stribling (1991, 1994); Ball (1982); Platts et al. (1983)

Source: Modified from Rankin (1995)

In the early 1980s, states began developing habitat assessment protocols to measure overall stream integrity and to demonstrate if streams were in compliance with their designated use requirements in order to meet the goals of the Clean Water Act. Ohio was one of the first states to implement a habitat assessment program to determine compliance with a designated use. As other states began developing their own habitat assessment protocols, it became more difficult to compare results between investigations and between states and regions. To facilitate the transfer of data and information between states, the USEPA developed the first Rapid Bioassessment Protocols (RBP) (Plafkin et al., 1989), which included a standardized "visual based" habitat assessment procedure. Barbour and Stribling have revised the original USEPA RBP in the past decade (Barbour et al., 1997).

In the past 20 to 25 years, the North Carolina Mecklenburg County Department of Environmental Protection (MCDEP) has conducted comprehensive efforts to assess the quality of streams within the county by monitoring biological and water quality indicators. However, one component that was not previously addressed by the MCDEP's biological and water quality program was the evaluation of the physical stream conditions through a stream habitat assessment program on a watershed scale. In order to select the most effective and appropriate method for characterizing stream and surrounding habitat conditions, the MCDEP conducted a watershed-scale pilot study to evaluate the usefulness of three standardized "visual based" habitat assessment protocols. The protocolswere selected through exclusionary and discretionary screening of many standardized stream habitat assessment forms prior to conducting the field work.

The exclusionary screening process was used to eliminate habitat assessment protocols focused on developing management strategies for fisheries programs. Protocols brought forward into the discretionary screening included those that were designed to be used for aquatic integrity assessments. A list of these protocols is shown in Table 2, listed by the reference and/or states in which they are used.

TABLE 2
Habitat Assessment Protocols Brought Forward for Phase 2 Screening

Document/Use by	Source	Comments *
Draft EPA RBP 1987	Plafkin et al. (1987)	• 15 habitat assessment parameters:4 in the primary, 3 in the secondary, and 8 in the tertiary categories • Score rangesare variableparameters are weighted • Low scores indicate better habitat integrity • One form was developed that is applicable tovarious stream types
Final EPA RBP 1989	Plafkin et al. (1989)	• 9 habitat assessment parameters: 3 in the primary, 3 in the secondary, and 3 in the tertiary categories • Score ranges are variable; thus, parameters are weighted • One form was developed that is applicable to various stream types
Alabama RBP	Plafkin et al. (1989)	• 9 habitat assessment parameters: 3 in the primary, 3 in the secondary, and 3 in the tertiary categories • Score ranges are variable; thus, parameters are weighted • One form was developed that is applicable to various stream types
Florida	Florida Department of Environmental Protection (1996)	• 7 habitat assessment parameters: 3 in the primary, 1 in the secondary and 3 in the tertiary categories • Scores range from 0 to 20 and all parameters are weighted equally • One form was developed that is applicable to various stream types
Revised Protocols Barbour and Stribling (1991)	Barbour and Stribling (1991)	• 9 habitat assessment parameters: 3 in each of the three (primary, secondary, and tertiary) physical stream habitat categories • Scores range from 0 to 20 and all parameters are weighted equally • Dual assessment system using two forms based on stream energy: one form for riffle/run and the other for glide/pool
USEPA 1997 Revised RBP	Barbour et al. (1997)	• 10 habitat assessment parameters: 3 in the primary, 4 in the secondary, and 3 in the tertiary categories (Barbour et al., 1997) • Scores range from 0 to 20 and all parameters are weighted equally • Dual assessment system using two forms based on stream energy, one form for riffle/run the other for glide/pool
Revised Protocols Barbour and Stribling (1994)	Barbour and Stribling (1994)	• 12 habitat assessment parameters: 4 in each of the three (primary, secondary, and tertiary) physical stream habitat categories • Scores range from 0 to 20 and all parameters are weighted equally • Dual assessment system using two forms based on stream energy: one form for riffle/run and the other for glide/pool
Georgia RBP	Modified by Barbour and Stribling (1991)	• 10 habitat assessment parameters: 3 in the primary, 4 in the secondary, and 3 in the tertiary categories • Scores range from 0 to 20 and all parameters are weighted equally • A dichotomous key is followed that minimizes variability between observes scoring a site; however, the key is cumbersome and time consuming to use • Dual assessment system using two forms based on stream energy: one form for riffle/run and the other for glide/pool

TABLE 2
Habitat Assessment Protocols Brought Forward for Phase 2 Screening

Document/Use by	Source	Comments *
Tennessee RBP	Barbour (1994)	• 10 habitat assessment parameters: 3 in the primary, 4 in the secondary, and 3 in the tertiary categories • Scores range from 0 to 20 and all parameters are weighted equally • Dual assessment system using two forms based on stream energy: one form for riffle/run and the other for glide/pool
Ohio EPA QHEI	Rankin (1989)	• 7 habitat assessment parameters: 4 in the primary, 1 in the secondary, and 2 in the tertiary categories • Score ranges are variable; thus, parameters are weighted • One form was developed that is applicable to various stream types
North Carolina	North Carolina Department of Environment and Natural Resources (1997)	• 8 habitat assessment parameters: 2 in the primary, 3 in the secondary, and 3 in the tertiary categories; having more than one choice in the decision process increases the precision with which habitats can be described • Score ranges are variable; thus, parameters are weighted • One form was developed that is applicable to various stream types
Field and Laboratory Methods for Macroinvertebrate and Habitat Assessment of Low-Gradient, Nontidal Streams	Mid-Atlantic Coastal Stream Workgroup (1997)	• 7 habitat assessment parameters: 3 in the primary, 1 in the secondary and 3 in the tertiary categories • Scores range from 0 to 20 and all parameters are weighted equally • One form was developed that is applicable to various stream types

* Primary category = Instream habitat conditions for biota
Secondary category = Channel shape
Tertiary category = Bank and riparian zone conditions

The final three habitat protocols selected for evaluation in the field pilot study were the modified Barbour and Stribling method developed by the Georgia Department of Natural Resources (GADNR); the North Carolina Department of Environment and Natural Resources (NCDENR) protocol; and the Ohio EPA's Qualitative Habitat Evaluation Index (QHEI).

The pilot study involved walking most of the lengths of two representative streams and documenting the physical habitat conditions of the stream and riparian zones by using the prescribed field forms, taking photographs, and recording general physical conditions. Three to five observers provided independent evaluations of the three different protocols that were used to document their understating and interpretation of the data collection and to show variability, if any, in the results. The representative streams used for the pilot study (McMullen Creek, located in an urban portion of the county, and Gar Creek, located in a rural setting) are characterized by a range of different land uses. The observers evaluated the mainstems, tributaries, and headwaters that constitute the hydrologic components of these two watersheds.

The results of the pilot study, using the three protocols and independent observes are shown in Figures 1 and 2. In order to compare the results among the three different protocols, the scores were normalized by dividing the total assigned score assessed in the field by the total possible score per field sheet. Thus the points in the scatter graphs are the normalized values represented as a percentage of the total possible score for each individual data sheet.

FIGURE 1. McMullen Creek, Mecklenburg County Summary

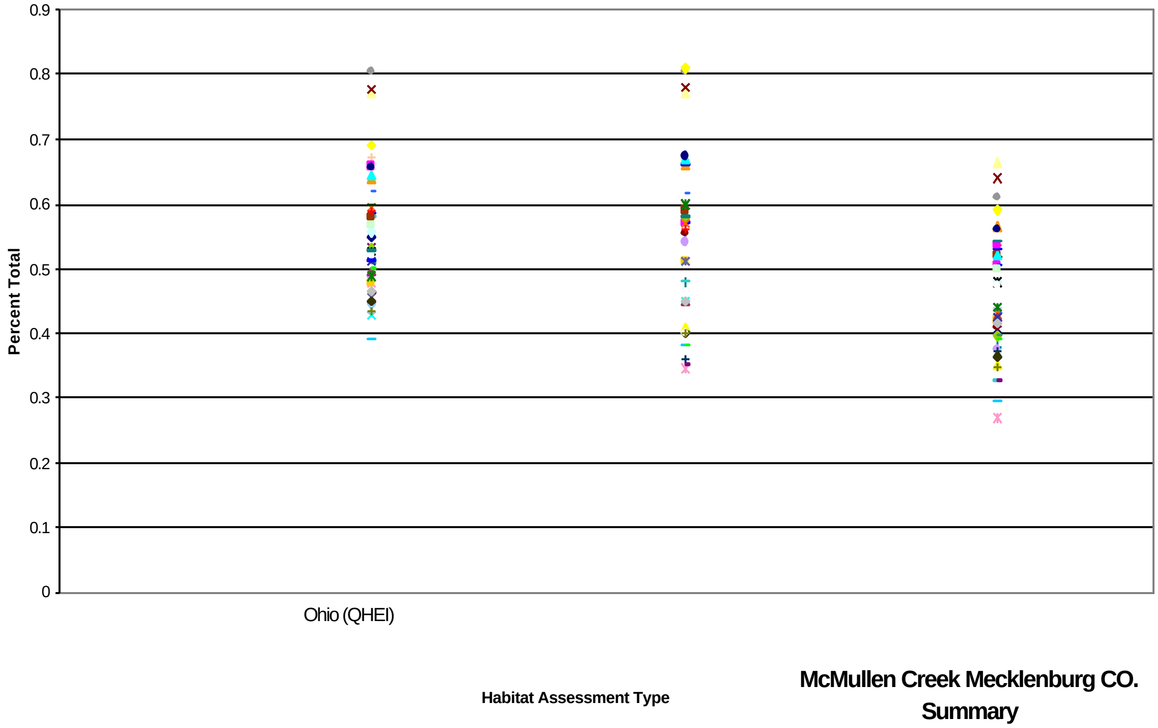
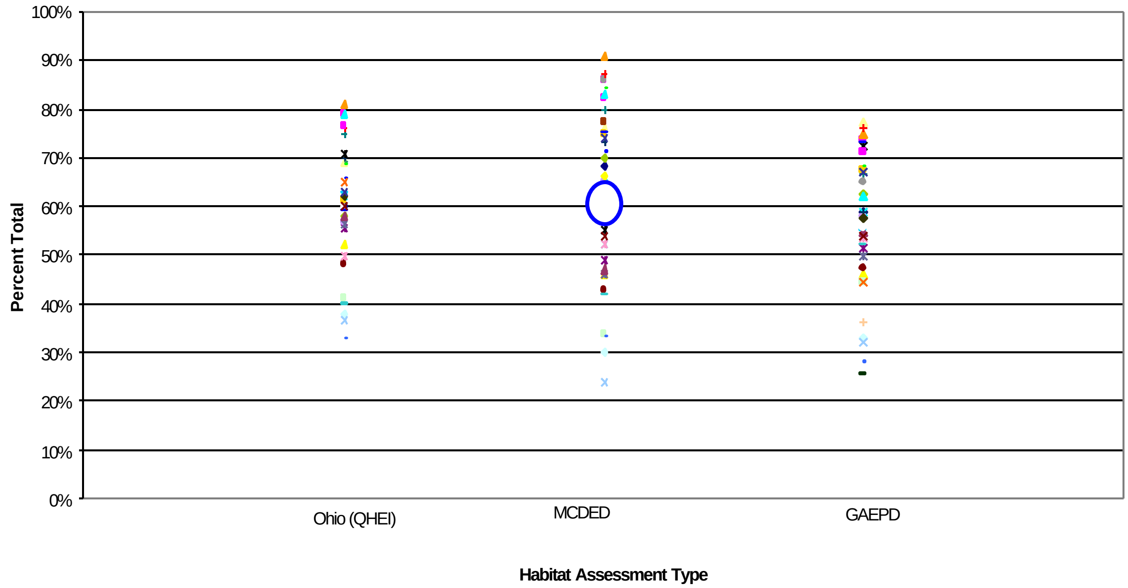


FIGURE 2. Gar Creek, Mecklenburg County Summary



Several trends and conclusions can be inferred from Figures 1 and 2:

- The QHEI and modified GADNR Barbour and Stribling protocols produced more similar scores at individual stations as compared to the NCDENR protocol.
- For streams that had relatively good infaunal and riparian habitats but poor bank conditions, the QHEI form resulted in slightly higher scores than the GADNR protocols. This was due to the weighting factor associated with bank stability.
- Scores using the NCDENR protocols for streams with relatively undisturbed habitats were generally higher than those obtained using the QHEI or modified GADNR Barbour and Stribling protocols. However, for streams with more disturbed habitats, the NCDENR protocols scored slightly lower. This resulted in a bimodal distribution of the data, as shown in the NCDENR column in Figure 2. This bimodal distribution, compared to the more uniform spread of the data points using the modified GADNR Barbour and Stribling and QHEI forms, indicates that the response of the NCDENR form may be less sensitive for the range of stream habitats evaluated in this pilot study.
- In areas where stream channels have been modified due to livestock activities or increased flow resulting from changes in land use and impervious areas, channel alteration may be underestimated using the modified GADNR Barbour and Stribling form because instructions are not clearly stated for this metric.

The field observers also commented on the general uses of the forms and instructions under field conditions as follows:

- Habitat assessment forms are inherently equally subjective.
- Results between reviewers are variable but variability is reduced considerably with experience.

- Internal field quality assurance/quality control (QA/QC) review and independent assessment by field team members is critical and reduces variability.

The habitat assessment protocols were screened using the criteria listed in Table 3. This screening evaluation showed that each of the forms has redeeming features that give it certain advantages over the others. However, when all the favorable/unfavorable designations for all eight criteria are compiled (Table 3), the GADNR modified Barbour and Stribling protocol was more suitable for Mecklenburg County's purposes than the other protocols, since it was rated favorably for six criteria as opposed to four for the other two. The GADNR Barbour and Stribling habitat assessment protocol was adopted for the countywide program with minor modifications.

Since the Mecklenburg County project, numerous habitat assessment stream walks have been conducted for watershed wide programs in Piedmont and Coastal Zone physiographic provinces, including over 400 miles in Virginia, about 200 miles in North Carolina, and 200 miles in Georgia. For these projects, the habitat assessment protocols and metrics have been adjusted slightly for purposes of clarification and to further minimize subjectivity during use and variability of the results.

TABLE 3
Favorability Ratings of the Three Habitat Assessment Protocols with Regard to the Screening Criteria

	Habitat Assessment Protocol		
Screening Criteria	**GADNR Modified Barbour and Stribling**	**NCDENR**	**QHEI**
1. Parameters clearly defined	X	X	X
2. Parameters characterize a range of conditions	X		X
3. Parameter attributes minimize subjectivity	X		
4. Parameters suitable for SE region, flexible	X	X	X
5. Methodology reflects local limiting factors	X	X	
6. Methodology enables assessment of biodiversity	X		
7. Easy to use		X	X
8. Requires little experience/training			
Totals:	6	4	4

Note: An 'X' indicates that this protocol was considered favorable with regard to the given screening criterion

Habitat Assessment Metrics

An evaluation of habitat quality is critical to any assessment of ecological integrity. The habitat quality evaluation is accomplished by characterizing selected physical parameters that represent stream conditions. Metrics for the visual based approach depend on several conditions to accurately assess the quality of the physical habitat structure:

- The metrics selected to represent the various features of habitat structure need to be relevant and clearly defined.

- The metrics must be sensitive to a continuum of conditions from the optimum to the poorest.
- The judgement criteria for the attributes of each parameter should minimize subjectivity through quantitative measurements or specific categorical choices.

Table 4 is a list of metrics cited in the literature and adopted by many states and environmental groups, including the USEPA, to conduct "visual based" stream and riparian zone assessments for their biological and aquatic quality monitoring programs. Several of these metrics were tested and evaluated in the development of watershed-wide assessment protocols for several municipalities in Virginia and the southeast. The table lists a description of each metric and its relevance to instream aquatic integrity.

TABLE 4
Habitat Assessment Metrics

Metric	Description	Comment
Epifaunal Substrate/Available Cover	Include the relative quantity and variety of natural structures in streams such as cobble, large rocks, fallen trees, logs and branches, feeding, or sites for spawning and nursery functions of aquatic macrofauna.	High and low gradient streams. Variability occurs percent area coverage is misinterpreted.
Embeddedness	Refers to the extent to which rocks (gravel, cobbles, and boulders) are sunk into the silt, sand, or mud of the stream bottom.	High gradient streams. It may also be useful to lift a few rocks in riffle areas and observe the extent of the dark area on their underside. Observations should be taken in the upstream and central portions of riffles (i.e., run).
Pool Substrate Characterization	Evaluates the type and condition of bottom substrates found in pools. Firmer sediments and rooted aquatic plants support a wider variety of organisms than a pool substrate dominated by mud or bedrock and no plants.	Low gradient streams. Observations require visual inspection of pool substrate.
Velocity depth combinations	Patterns of velocity and depth combinations: 1 Slow – Deep, 2 Slow – Shallow, 3 Fast –Deep, 4 Fast – Shallow.	High gradient streams.Guidelines are 0.5 m depth to separate shallow from deep and 0.3 m to separate fast from slow. Guidelines may not be sensitive to discriminate between large and small stream systems.
Pool variability	Rates overall mixture of pool types according to size and depth. In rivers with low sinuosity (few bends) and monotonous pool characteristics, very little instream habitat variety exists to support a diverse community. The four basic types of pools are large-shallow, large-deep, small-shallow, and small-deep.	Low gradient streams. Any pool dimension (e.g., length, width) greater than half the crosssection of the stream is a large pool. Small pools have length and width dimensions less than half the width of the stream. Pools with depths greater than 1.0 m are deep. Shallow pools are less than 1.0 m deep. Guidelines may not be sensitive to discriminate between large and small stream systems.
Sediment Deposition	Relates to the amount of sediment that has accumulated and the changes that have occurred to the stream bottom as a result of deposition. Sediment deposition may cause the formation of islands, point bars (areas of increased deposition usually at the beginning of a meander that increase in size as the channel is diverted toward the outer bank) or shoals, or result in the filling of pools.	High and low gradient streams. Estimation of growth of point bars requires observers visually determine if they are stable (e.g., presence of vegetation).
Channel Flow status	Is the degree to which the channel is filled with water during normal flow periods. Flow status changes as channel enlarges. Useful for interpreting biological condition during abnormal or lowered flow conditions.	High and low gradient streams. This is a seasonal parameter. A decrease in water will wet smaller portions of the streambed, thus decreasing available habitat for aquatic organisms. Observers use the toe of slope and vegetation line on the lower bank as reference point to estimate channel flow status. Variability occurs if stream is a "C" type or if "C" in forming in an "F" channel.

TABLE 4
Habitat Assessment Metrics

Metric	Description	Comment
Channel alteration	Measurement of large-scale alteration of instream habitat, which affects stream biotic integrity and causes scouring. Channel alteration is present when: artificial embankments, rip rap, and other forms of artificial bank stabilization or structures are present; when dredging has altered bank stability; when dams and bridges are present; when banks and channels have been disturbed by livestock, other agricultural practices; or hydrology; and when other changes have occurred.	High and low gradient streams. Variability occurs when discriminating between natural conditions and induced by development or other human use.
Frequency of riffles	Measure of sequence of riffles and the heterogeneity occurring in a stream. A riffle/run (i.e., distanced between riffle divided by width of stream) ratio is use to as a measure of heterogeneity.	High gradient streams. Observers must estimate distance between riffles. For high gradient streams were riffles are uncommon, a run/bend rations is used.
Channel sinuosity	Evaluates the meandering or sinuosity of the stream.	Low gradient streams. Run/bend ration may not necessarily provide an accurate measurement. Stream length divided by valley length requires map measurements.
Bank stability	Measures the existence of or the potential for detachment of soil from the upper and lower stream banks and its movement into the stream. Steep banks are more likely to collapse and suffer from erosion than are gently sloping banks, and are therefore considered to be unstable. Signs of erosion include crumbling, unvegetated banks, exposed tree roots, and exposed soil. Reinforcement of banks via rocks, artificial or natural, provides stability.	High and low gradient streams. Observers must evaluate bank soil condition, slope, shape, root mat density, etc.
Bank vegetative protection	Measures the amount of the stream bank that is covered by vegetation. This parameter supplies information on the ability of the bank to resist erosion. Banks that have full, natural plant growth are better for fish and macroinvertebrates than those without vegetation protection and those shored up with concrete or riprap.	High and low gradient streams. Observers must consider when scoring vegetative protection: (1) is the vegetation native or natural or planted and introduced (2) is the upper story, under story, and ground cover vegetation well balanced; (3) what is the standing crop biomass; and (4) during which season are you conducting this assessment.
Vegetation buffer zone width	Measures the width and conditions of the vegetation or land use from the edge of the upper stream bank out through, and in some cases, beyond the flood plain and riparian zone. The vegetative zone serves as a buffer to pollutants entering a stream from runoff, and minimizes erosion.	High and low gradient streams. Observers must walk around in the buffer area, paying close attention to the amount of natural vegetation present and how deep it extends from the bank, and disturbances that may effect the transport of pollutants through the zone. Vegetated buffer zone assessment involves documenting three condition factors: 1) vegetation cover type, 2) breaks, and 3) vegetated zone width.
Canopy cover	Measures the amount of cover overhead that provides shading and cooling of the water.	High and low gradient streams. Assessment involves vegetation cover type, and density of leaf material. Metric is sensitive to season and size of stream.
Aesthetics	Measures the perception of what constitutes desirable surface water and aquatic integrity.	High and low gradient streams. Highly subjective and does not necessarily relate to the ability of a stream to support aquatic life.
Riffle/run depth	Measures habitat conditions for fish habitat and refuge.	High and low gradient streams. Established pool or riffle depths may not be sensitive to discriminate between large and small stream systems.

TABLE 4
Habitat Assessment Metrics

Metric	Description	Comment

In Table 5, habitat assessment metrics were evaluated for their sensitivity to accurately measure and document the conditions and represent the stream and riparian features. Overall, the metrics evaluated would respond to the expected field conditions and support watershed management decisions. Those with mostly high probability ratings are most useful for collecting reliable and reproducible data and describing the systems being evaluated. No one metric could be eliminated based on the criteria established; however, some metrics are redundant and some are highly subjective such as aesthetics.

TABLE 5
Efficacy of Habitat Assessment Metrics with Regard to the Screening Criteria

Metric	Feature Expected for Different Ecoregion	Differentiate Between Good and Bad Streams	Reproducible	Works in Small and Large Streams	Level of Subjectivity	Supports Watershed Management Decisions
Instream Cover	Medium	High	Low	Medium	Medium	High
Epifaunal/Bottom Substrate	Low	High	High	Medium	Medium	High
Embeddedness	Low	High	Medium	High	Medium	Medium
Channel/Bank Alteration	High	High	Medium	High	Medium	High
Sediment Deposition	Low	High	High	High	Medium	Medium
Frequency of Riffles	Low	High	Medium	High	Medium	Medium
Channel Flow Status	High	Low	High	High	Medium	Medium
Bank Vegetation Protection	High	Medium	Medium	Medium	Medium	Medium
Bank Stability	High	Medium	Medium	High	Medium	High
Vegetative Buffer Zone Width	High	High	High	High	High	High
Pool Substrate Characterization	Medium	Medium	High	Low	Medium	Medium
Pool Variability	Medium	Medium	Medium	Low	Medium	Medium
Channel Sinuosity	Medium	Medium	Medium	High	Medium	Medium
Velocity/Depth Regimes	Low	High	High	Low	Medium	Medium
Aesthetics	Medium	Medium	Medium	High	Low	Low
Canopy cover	Medium	Medium	Medium	Low	Medium	Medium
Development of Riffle/Run	Low	High	High	Medium	Medium	Medium
Riffle/Run Depth	Low	High	High	Medium	Medium	Medium

Infrastructure Inventory

The infrastructure inventory was developed as part of the Henrico County Stream Assessment Project to:

- Identify potential sources of contamination
- Identify bank erosion and degraded aquatic integrity

- Identify locations for potential spot improvements
- Inventory county infrastructure in and around the stream channel

The protocols are primarily focused on sources of bank and bed erosion. The inventory includes protocols for evaluating pipes, ditches, obstructions, dump sites, head cuts, public utility lines, erosion problem areas, road and other stream crossings, and areas of deficient buffer vegetation. The protocols capture information that is readily available from visual observations of each inventory point.

Based on the inventory results, management decisions can be made to prioritize improvement projects in critical areas.

Stream Characteristics

The stream characteristics form was developed as part of the Henrico County Stream Assessment Project to record general stream information and to capture visual information on stream quality. This form is also a single location to capture notes and comments about the reach that may not be well represented in the other forms, such as specific restrictions to stream restoration or conversations with local residents. Information captured in this form includes general stream information such as stream name, watershed, and reach length, as well as instream quality indicators such as observations of water appearance, odors, and organisms.

Geomorphic Classification of Stream Type

A Rosgen Level 1 morphological evaluation will be conducted during the stream assessment. The morphology (form and structure) of the stream channel is governed by the laws of physics and is documented through observable stream channel features, such as channel width and depth and measurements of related stream processes such as stream flow and velocity. According to Leopold et al., (1964) stream channel pattern is directly influenced by eight major variables:

- Bankfull depth
- Bankfull channel width
- Velocity
- Discharge
- Channel slope
- Roughness of channel materials
- Sediment load
- Sediment size

A change in any one of these variables sets up a series of channel adjustments that leads to changes in one or more of the others, resulting in channel pattern alteration (and often accompanying erosion and other kinds of channel instability). Bankfull measurements are probably the most important variables for making a stream type determination.

The Level 1 Rosgen assessment provides data for a classification system for streams in which a morphological arrangement of characteristics (such as channel shape) is used to organize relatively similar stream types. In the Rosgen classification system, morphological data are collected to characterize the dominant features in each reach. For this study, similar data are collected throughout the reaches being evaluated, focusing on the bankfull cross sectional measurements. The morphological data are used to categorize a particular reach as one of eight stream types (Rosgen, 1996).

Table 6 summarizes the stream types and assessment criteria. Assigning a stream type to a reach is an iterative process in which the data for each feature are compared to the criteria. This assignment will occur in the office once all field data have been collected. Stream classification may be used to determine the evolutionary stage of development, stream stability, and stream degradation potential.

TABLE 6
General Stream Type Descriptions and Delineation Criteria

Stream Type	General Description	Entrenchment Ratio [a]	W/D [b] Ratio	Sinuosity [c]	Slope %
A	Steep, entrenched, cascading, step/pool streams. High-energy debris transport associated with depositional soils. Very stable if bedrock- or boulder-dominated channel.	<1.4	<12	1.0 to 1.2	4 to 10
B	Moderately entrenched, moderate gradient, riffle-dominated channel, with infrequently spaced pools. Very stable plan and profile. Stable banks.	1.4 to 2.2	>12	>1.2	2 to 4
C	Low gradient, meandering, point-bar, riffle/pool, and alluvial channels with broad, well-defined floodplains.	>2.2	>12	>1.2	<2
D	Braided channel with longitudinal and transverse bars. Very wide channel with eroding banks.	Not applicable	>40	Not applicable	<4
DA	Anasotomosing (multiple or braided channels) narrow and deep with extensive, well vegetated floodplains and associated wetlands. Very gentle relief with highly variable sinuosities and width/depth ratios. Very stable stream banks.	>2.2	Highly variable	Highly variable	<0.5
E	Low gradient meandering riffle/pool stream with low width/depth ratio and little deposition. High meander/width ratio and sediment supply.	>2.2	<12	>1.5	<2
F	Entrenched meandering riffle/pool channel on low gradients with high width/depth ratio.	<1.4	>12	>1.2	<2
G	Entrenched “gully” step/pool and low width/depth ratio on moderate gradients. Very unstable unless massive amounts of vegetation present on stream banks.	<1.4	<12	>1.2	2 to 4

Source: Rosgen, 1996
[a] A measure of channel incision – Floodplain width divided by bankfull channel width
[b] Bankfull channel (W)idth divided by bankfull channel (D)epth
[c] A measure of stream meander – Stream length divided by valley length